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Jens Eger, Lennart Kaplan and Henrike Sternberg

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Platz der Göttinger Sieben 5 | 37073 Göttingen

vwl-verwaltung@uni-goettingen.de | www.uni-goettingen.de/en/60864.html

How to reduce Vaccination Hesitancy? The Relevance of Evidence and its Communicator☆

Jens Eger[a,b], Lennart Kaplan[b,c,d*], and Henrike Sternberg[e]

[a] *DEval, German Institute for Development Evaluation, Bonn, Germany*

[b] *Georg-August University, Göttingen, Germany*

[c] *Deutsches Institut für Entwicklungspolitik, Bonn, Germany*

[d] *Institut für Weltwirtschaft, Kiel, Germany*

[e] *School of Social Sciences and Technology, Technische Universität München, Munich, Germany*

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Abstract: While the world faces unprecedented COVID-19 case numbers, vaccination rates in many countries are stagnating. A differentiated understanding of the concerns of the unvaccinated population seems urgently needed to design successful communication strategies. We conducted an original survey experiment among 2,100 unvaccinated respondents from Germany where a substantial population share remains unvaccinated. Guided by the elaboration likelihood model, this paper has two objectives: First, it explores by means of a latent class analysis how unvaccinated individuals might be characterised by their attitudes towards COVID-19 vaccination. The results suggest three different subgroups: Vaccination *opponents*, *sceptics* and those *receptive* to be vaccinated. Second, we investigate to what extent (i) communicators (scientists/politicians) can employ (ii) varying types of evidence (none/anecdotal/statistical) to improve vaccination intentions across these subgroups. While vaccination *opponents* seem largely unreachable, *sceptics* value information by scientists, particularly if supported by anecdotal evidence. *Receptives* seem to instead value statistical evidence from politicians.

Keywords: Vaccination hesitancy; COVID-19; Elaboration Likelihood Model; Latent Class Analysis; Persuasive messaging; Evidence provision

JEL codes: D91, H12, I12, I18

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*Corresponding author at: Chair of Development Economics, Georg-August-Universität Göttingen, Platz der Göttinger Sieben 3, 37073 Göttingen.

E-mail addresses: jens.eger@DEval.org (J. Eger), lennart.kaplan@wiwi.uni-goettingen.de (L. Kaplan), henrike.sternberg@tum.de (H. Sternberg)

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Declarations of interest: none

1 Introduction

Many countries around the world are currently facing a key challenge: how to convince their populations to get vaccinated against COVID-19. Despite existing vaccination capacity and evidence on vaccine efficacy (Kim and Lee, 2022), low vaccine acceptance in the Global North poses the risk that herd immunity will not be achieved. Similar to several other European countries, Germany was hit strongly by the fourth wave of the pandemic in autumn 2021 and is struggling to find the right policies amidst higher levels of contagiousness of the Delta and Omicron variant. The government introduced increasing restrictions on unvaccinated persons in response to the stagnating national vaccination rate, which currently remains at barely 75% (i.e., those having received two doses (Robert-Koch-Institut (RKI), 2022)). Well-designed information campaigns are, thus, urgently needed. Yet, only if the needs and concerns of the unvaccinated are sufficiently understood, policy makers can design persuasive information campaigns that help to increase vaccination willingness (Courbage and Peter, 2021). Against this background, our paper engages in a differentiated classification of the unvaccinated population and builds on socio-psychological theory to assess how vaccine efficacy-related evidence provision through different communicators could increase vaccination willingness.

Existing research suggests that the judgment of information largely depends on the perception of trustworthiness and credibility of its communicator (e.g., Hewgill and Miller, 1965). Particularly for vaccinations, recent empirical evidence confirms the importance of a trustworthy communicator for the willingness to get vaccinated (Argote et al., 2021; Betsch et al., 2020). For instance, Alsan and Eichmeyer (2021) document that social proximity between the information communicator and the recipient is key for providing credible messages. To increase their trustworthiness, communicators may support their information with evidence (O'Keefe, 1998; Reinard, 1998). An extensive literature on persuasion processes addresses the effects of information and information attributes on attitude change (see O'Keefe, 2015, for a review).

According to the dual-process theory of the Elaboration-Likelihood Model (ELM) (Chaiken and Trope, 1999), the processing of persuasive messages can occur through two distinct pathways: The first path (called the "peripheral route") runs through quick cognitive shortcuts; the second path (called the "central route") builds on more elaborate cognitive processing and deliberate reasoning (e.g., Strack and Deutsch, 2015). Thus, different types of evidence may match better with the respective processing path. Specifically, a distinction can be made between two types of evidence, amongst others: statistical and anecdotal. Previous research has shown that when subjects do not engage in deep elaboration, anecdotal evidence is more convincing (Betsch et al., 2011; Haase et al., 2015) since it is more descriptive and easier to process via the peripheral route (Hoeken, 2001). In contrast, statistical evidence is likely to be particularly compelling if the respective population considers the subject as salient and engages via the central route. Given heterogeneities in the population and their attitudes towards different communicators, we propose that communicators may optimize the effectiveness of their message by choosing the evidence type that best complements their own credibility and macthes the recipient of the information. We examine these theoretical expectations within a unique sample of unvaccinated German citizens (N=2,100) who participated in an online survey experiment specifically targeting this critical share of the population.

The contribution of this paper is threefold. First, we engage in a latent class analysis to characterize unvaccinated individuals based on their attitudes towards the COVID-19 vaccination. In doing so, we conceptually rely on the 5C-scale of vaccination hesitancy (Betsch et al., 2018). Second, we combine this classification with the theoretical framework of the ELM to consider experimentally how different forms of evidence (none/statistical/anecdotal) and different communicators (politicians/scientists) may target individuals within the identified subgroups (classes) to achieve increased vaccination uptake. Treatment effects might vary significantly across classes if either the motivation or the ability to engage in information elaboration also varies between classes. To the best of our knowledge, this is the first study that considers the potential complementarity between communicator and evidence to increase messaging effectiveness and assesses treatment effect heterogeneity across different subgroups of unvaccinated respondents [1].

The latent class analysis results reveal that unvaccinated individuals are not a homogeneous group but instead can be characterized as vaccination *opponents*, *sceptics*, and receptives. Findings of the survey experiment suggest that, on average, for the entire sample of unvaccinated respondents, scientists are more persuasive information communicators than politicians, whereby the supporting evidence type seems to be less relevant. Furthermore, the heterogeneity analysis shows that different communication strategies are promising for the different identified subgroups. While vaccination *opponents* do not seem reachable by any of the employed strategies, vaccination *sceptics* react particularly positively to scientists as communicators. Interestingly, the results suggest that anecdotal evidence communicated by scientists may especially be a useful communication strategy for this subgroup. *Receptives*, as the third group, seem already largely convinced of the benefits of a COVID-19 vaccination. To finally motivate respondents within this group to get vaccinated, statistical evidence from politicians appears most persuasive.

The remainder of the paper is structured as follows. Section 2 briefly presents materials and methods, introduces the empirical strategy, and outlines the experimental approach. Subsequently, Section 3 presents the results of the latent class analysis and our experimental findings. Section 4 concludes with a brief discussion of the main findings and outlines avenues for future research.

2 Material and Methods

2.1 Setting and sampling

We conducted an online survey with a sample of 2,145 unvaccinated individuals from Germany between August 20 and September 16, 2021. Respondents were recruited from a German online access panel maintained by the survey company Respondi. Individuals were eligible to participate in the study if they were at least 18 years old and had not yet been vaccinated against COVID-19 (not yet received the first dose). The survey covered socioeconomic characteristics, measures regarding respondents' elaboration likelihood to engage with information about COVID-19

[1] For an overview of our proposed hypotheses, please see https://osf.io/vhjeg/. For specifications of pre-analysis plan deviations, see Appendix A

vaccines, and their intentions to get vaccinated. Respondents received 'mingle points' (worth roughly 1 Euro) for participating in the survey, which they could redeem as cash, vouchers, or donations. The ethical review board of Göttingen University reviewed the study prior to implementation (Ethikkommission, date 15/07/2021).

2.2 Empirical strategy

Latent class analysis

According to the ELM, behavioral intentions are affected by one's motivation and ability, e.g., education (Maurer, 2009), to engage with available information. Thus, to assess how different responsiveness to communicators and evidence affects COVID-19 vaccination intentions, we first classified and characterized different groups of unvaccinated respondents based on their differential attitudinal patterns towards COVID-19 vaccinations. For this purpose, we conducted a Latent Class Analysis (LCA). This analysis was an explorative component of the information experiment as outlined in the Pre-Analysis-Plan[2].

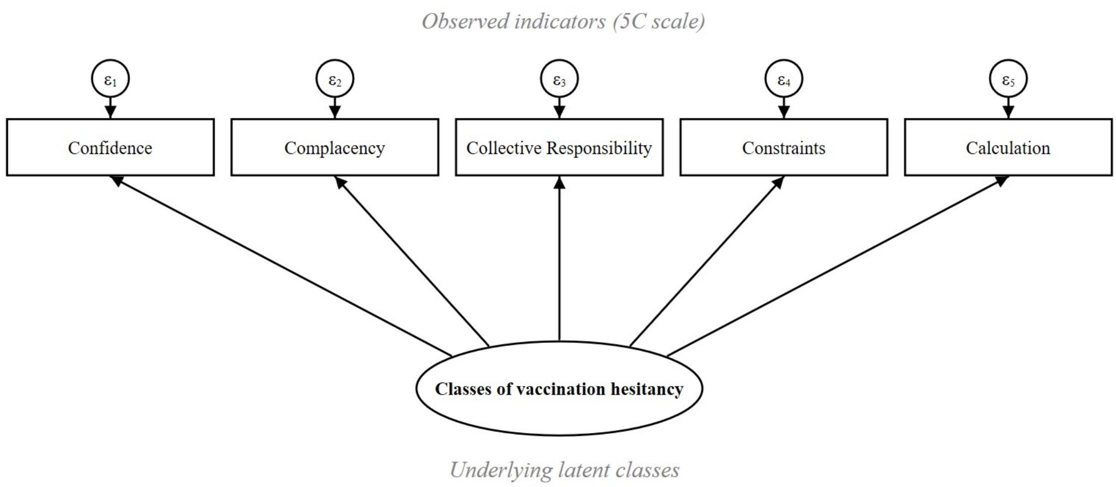

Fig. 1. LCA model: Identification of classes of vaccination hesitancy. *Notes:* Authors' own depiction.

The purpose of LCA is to condense numerous observed ordinal variables (reflective indicators) to assign probabilities of belonging to a smaller set of underlying, latent classes (Hagenaars and McCutcheon, 2002). By reducing dimensionality, LCA facilitates subgroup analyses (Lanza and Rhoades, 2013) which makes it particularly useful to assess heterogeneous effects in experiments (Lancsar et al., 2022). As reflective indicators, we considered the extended COVID-19-adapted 5C scale by Betsch et al. (2018). The scale captures five different aspects of vaccination intentions with three survey questions each (namely, Confidence, Complacency, Collective responsibility, Constraints, Calculation; see section 2.3 and Table A13 for details) - in our case intended to proxy the motivation component of the elaboration likelihood of respondents. The LCA method assumes that the underlying latent class membership (i.e., here classes of vaccination hesitancy) induces differential response patterns in the reflective indicators (i.e., here the 5C scale questions).

[2]For the experimental protocol and the survey, please refer to the supplementary materials and the pre-analysis plan at `https://osf.io/vhjeg/`.

Thus, in the LCA, the 5C scale indicators are the dependent variables and the categorical latent class variable is the independent variable, as illustrated in Figure 1 below. Based on this, we estimated a generalized structural equation model by means of an ordered logistic regression using maximum likelihood estimation.

Survey experiment

The second component of the empirical strategy comprised a survey experiment testing different information treatments about the benefits of a COVID-19 vaccination to identify persuasive communication strategies. Specifically, we first informed all participants about the current COVID-19 incidence in Germany (at the time) and described a hypothetical scenario in which a new COVID-19 vaccine had been developed and approved. In a second step, respondents were informed that this newly developed and approved vaccine is highly effective in reducing hospitalization following a COVID-19 infection[3]. This second step varied randomly regarding two components: (i) the communicator's identity and (ii) the type of evidence employed by the communicator. In our case, anecdotal evidence referred to a visit to an intensive care unit, while we considered as statistical evidence a clinical study on the efficacy of the new hypothetical COVID-19 vaccine. Appendix A provides the exact wording of the experimental treatments.

We estimated OLS and ordered logit models to test the main hypotheses whether evidence increases vaccination willingness and whether heterogeneous messaging and respondent characteristics moderate this effect.

$$VI_i = \alpha + \beta_1 Evi_i \times Com_i + \beta_2 Com_i + \beta_3 Evi_i + \epsilon_i \tag{1}$$

VI_i in Equation 1 refers to the vaccination intentions of respondent i, Com_i denotes whether a politician or scientist communicated the information treatment, Evi_i refers to the type of provided evidence (none/anecdotal/statistical), and ϵ_i is the error term. We also introduced a triple interaction term by including LCA_i to consider how the different subgroups of unvaccinated respondents (i.e., the identified classes of vaccination hesitancy) react to the differential messaging. Since there is uncertainty in the class assignment when using LCA, we employed a multiple imputation approach to address this. Appendix A provides further detail regarding how this was addressed.

2.3 Data and outcome variables

Beyond the information about treatment group assignment, the survey covered information on the main dependent variable of interest: the intention to get vaccinated against COVID-19. We moreover collected information on additional explanatory variables, including demographic and socioeconomic characteristics of respondents. The core survey items are summarized in Tables A1 and A13 in Appendix B.

[3]We deliberately did not specify any existing COVID-19 vaccines to avoid capturing preferences for certain producers, but indicated an efficacy that matches the preferred vaccines currently in use in Germany (BioNTech and Moderna).

2.3.1 Vaccination intention

The main outcome variable is respondents' intention to get vaccinated against COVID-19, measured on a 7-point Likert scale. We elicited vaccination intentions by asking respondents whether they would in the following week get vaccinated with the new hypothetical COVID-19 vaccine introduced in the survey experiment[4].

2.3.2 COVID-19 vaccination attitudes and elaboration likelihood

As outlined above, we employed the 5C scale by Betsch et al. (2018) as reflective indicators for the LCA. We adjusted this scale, initially designed for general vaccination attitudes, to fit a COVID-19 specific application based on Betsch et al. (2020). The scale aims to elicit five central aspects of attitudes towards vaccination, namely (i) Confidence in the COVID-19 vaccines and their endorsers, (ii) Complacency (not perceiving the virus as a serious risk), (iii) Collective responsibility (willingness to protect others), (iv) Constraints (structural and psychological barriers), and (v) Calculation (extensive information searching for weighing costs and benefits) (Betsch et al., 2018). We employed the full extended scale, which consists of three items for each aspect (i.e., 15 questions in total).

Moreover, the survey collected information to validate whether the LCA class assignment, in fact, captures the elaboration likelihood with which respondents take up the different information treatments. Specifically, we elicited trust in politicians and scientists (a proxy for motivation to engage with the provided information) and the perceived value and understanding of anecdotal and statistical evidence (a proxy for ability to engage with the provided information), all measured on a 7-point-Likert scale.

3 Results

3.1 Latent class analysis: Not one, but many publics

The results of the LCA suggest the existence of three underlying classes of vaccination hesitancy in our sample[5]. These three classes are characterized and distinguishable by differential response patterns to the COVID-19 adjusted 5C scale (see Figure 2 below and Tables A2-A5 in Appendix B)[6].

[4]For the exact wording of the outcome and other survey items, please see Table A13 in Appendix B.

[5]We ran models with one to four and partly five underlying classes, but opted for a final model with three classes due to a combination of interpretability, reductions in the goodness of fit improvements, and model convergence problems. In the LCA, where the model's fit can also be assessed for a single model using the likelihood-ratio test of the fitted model versus the saturated model (G2 statistic), we fail to reject the null hypothesis that our model fits just as well as the saturated model.

[6]While we initially measured agreement with the items of the 5C scale on a 7-point Likert scale, we condensed the scale into three categories due to skewed and non-normally distributed data, not allowing the model to converge. The three condensed categories combined the two extreme points of the initial Likert scale as well as the three moderate points (initial values 1 or 2 => condensed value 1; values 3,4 or 5 => value 2; values 6 or 7 => value 3). The resulting ordinal variables with three categories were then used as categorical indicators for the LCA. The initial 7-point Likert scale and the condensed scale are, on average, across all 15 items highly correlated by a value of approximately 0.95.

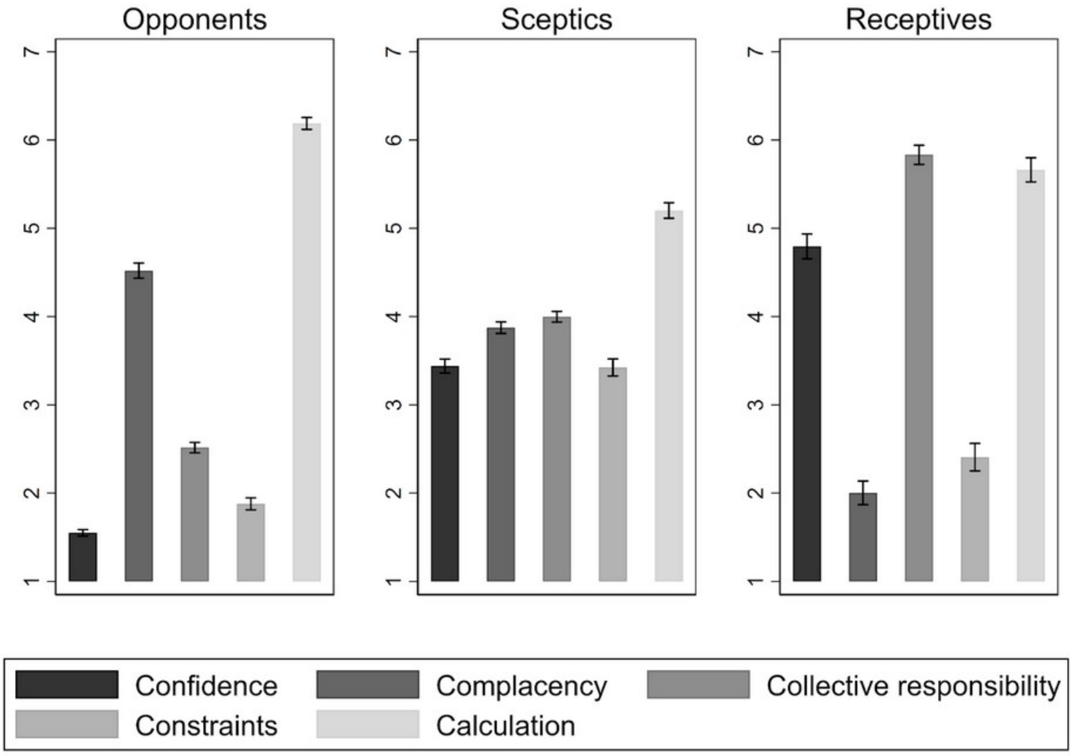

Fig. 2. Classes of Vaccination Hesitancy: Identification via the 5C Scale. *Notes:* Results refer to mean values of the 5C scale for vaccination attitudes, separately for each class as identified by the LCA. The mean values shown here are those of the initial 5C scale, measured on a 7-point Likert scale. See Tables A3-A5 in Appendix B for the condensed scale. Values of the 15 5C items (three items for each aspect) were averaged for each of the five aspects of vaccination hesitancy that we aim to capture. See Figure A1 in Appendix B for the same graphic with all 15 items. In order to better illustrate class differences regarding the 5C vaccination hesitancy scale, the graph employs a definite class assignment where respondents were assigned to the class with the maximum predicted probability.

A first class, vaccination *opponents*, had the largest prevalence in our sample (55.14%). This class was characterized by relatively low confidence levels in the vaccine, the system that delivers them, and the (motivations of the) actors deciding about the need for vaccines. Similarly, vaccination *opponents* expressed high levels of complacency (perceived invulnerability towards the COVID-19 virus) and low levels of collective responsibility, which may make them more susceptible to 'vaccination free-riding'. Finally, the aspect of calculation (i.e., in terms of intensive information searching to weigh infection and vaccination risks carefully) was a highly important factor, whereas practical constraints or inconveniences such as geographical accessibility did, on average, not seem to present a substantial barrier to vaccination in this underlying subgroup.

The second class with contrary characteristics, vaccination *receptives*, had the smallest prevalence in our sample (18.24%). While levels of (i) vaccine confidence and (ii) collective responsibility in getting vaccinated were on average relatively high, the degree of (iii) complacency was relatively low compared to the values in the class of vaccination *opponents*. Practical constraints to getting vaccinated were slightly more important among vaccination *receptives*, while calculation aspects were slightly less important than they were among vaccination *opponents*.

The third class, vaccination *sceptics*, had a prevalence of approximately one-quarter of our sample (26.63%). In this class, respondents attributed a similar, moderate relevance to all the investigated reasons against or in favor of a COVID-19 vaccination. The only exception was calculative considerations of the vaccination decision, which presented the most dominant factor in this class[7].

Following these classifications, we assume the elaboration likelihood (here, the motivation) to respond to COVID-19 vaccine communication strategies is relatively lower within the class of *opponents* than for members of the *sceptics* class, while it is likely the highest within the *receptive* class. In order to better assess the accuracy of the above interpretation of the three class' characteristics, Table A9 in Appendix B reports, for each class, the average willingness to get vaccinated with the new hypothetical COVID-19 vaccine introduced in the survey experiment. We find that, in line with the above characterization, the three classes differed linearly in their COVID-19 vaccination intentions with the hypothetical vaccine introduced in the survey experiment: Reported willingness was on average lowest among *opponents* (Mean=1.73; SD=1.23) and highest among the class of vaccination *receptives* (Mean=4.50; SD=2.00), while *sceptics* indicated moderate intentions to get vaccinated (Mean=3.43; SD=1.46)[8]. This pattern also holds for respondents' willingness to get vaccinated with the developed and broadly known COVID-19 vaccines (BioNTech, Moderna, Johnson&Johnson, AstraZeneca, Sputnik V, Sinopharm).

The three identified classes were represented in all population strata, although some differences could be identified (see Table 1 below). Regarding demographic and socioeconomic characteristics, the class of vaccination *opponents* differed from the other two classes, e.g., with respect to age, gender, educational attainment, and federal state of residence. The classes differed even more clearly in terms of their intentions and beliefs. Looking at respondents' (i) reported voting intentions in the next national election[9], (ii) their trust in scientists and (iii) politicians, as well as their perceived value and understanding of (iv) anecdotal and (v) statistical evidence, there seems to be a near-linear pattern across the three classes: The more sympathetic a class' attitudes towards a COVID-vaccination (i.e., *receptives* > *sceptics* > *opponents*), the less often respondents of this class indicated to vote for the AFD party in the next national election (a right-wing party in the German parliament, which opposed pandemic-related restrictions), the higher was their trust in scientists and politicians, the more they valued statistical evidence, and the less they valued anecdotal evidence. All these differences between each of the three classes were statistically highly significant.

At first sight, *opponents*' low elaboration likelihood - both with respect to ability (lower educational attainment) and motivation (low general vaccination motivation (5C), low perceived value of statistical evidence, and low trust in established societal actors as also evidenced by voting intentions) - may seem to discourage vaccination campaigns. Yet, given the differing levels of trust in communicators (politicians/scientists) and perceived value of different forms of evidence (anecdotal/statistical), the LCA may also inform different communication strategies, which we experimentally evaluate in the subsequent section.

[7]Due to the condensed indicators employed in the LCA, we additionally conducted a latent profile analysis (LPA) as a robustness check, which employs the initial 7-point Likert scale as continuous indicators of the latent classes. Class prevalences and characteristics (i.e., marginal class probabilities and class means) were very similar to in the LCA and are presented in Tables A6-A8 in Appendix B.

[8]While we argue for a differentiated assessment across the identified subgroups within the unvaccinated population, we also consider average effects within the entire sample of unvaccinated respondents (Mean: 2.69; SD: 1.84).

[9]The next national elections in Germany were held a couple of weeks after the survey was fielded.

Table 1
Respondent Characteristics by Class Membership.

Variable	(1) Opponents (N=1,184)	(2) Sceptics (N=572)	(3) Receptives (N=389)	T-test Difference (1)-(2)	T-test Difference (1)-(3)	T-test Difference (2)-(3)
Female	0.658 (0.014)	0.592 (0.021)	0.652 (0.024)	0.066***	0.006	-0.060*
18-34 yrs.	0.266 (0.013)	0.404 (0.021)	0.365 (0.024)	-0.138***	-0.099***	0.039
35-54 yrs.	0.527 (0.015)	0.484 (0.021)	0.460 (0.025)	0.043*	0.067**	0.024
55 yrs. and above	0.207 (0.012)	0.112 (0.013)	0.175 (0.019)	0.095***	0.032	-0.063***
Primary education	0.151 (0.010)	0.142 (0.015)	0.132 (0.017)	0.009	0.019	0.010
Secondary education	0.375 (0.014)	0.347 (0.020)	0.323 (0.024)	0.027	0.051*	0.024
Tertiary education	0.474 (0.014)	0.510 (0.021)	0.545 (0.025)	-0.036	-0.071**	-0.034
Residence in new federal states	0.272 (0.013)	0.243 (0.018)	0.198 (0.020)	0.029	0.074***	0.045
Intention to vote AFD	0.352 (0.013)	0.219 (0.015)	0.091 (0.012)	0.133***	0.261***	0.128***
Trust in scientists	3.716 (0.046)	4.229 (0.057)	5.532 (0.064)	-0.513***	-1.816***	-1.303***
Trust in politicians	1.613 (0.029)	2.962 (0.061)	3.653 (0.085)	-1.348***	-2.040***	-0.691***
Value/Understanding of anecdotal evidence	3.708 (0.028)	3.458 (0.036)	3.126 (0.055)	0.250***	0.582***	0.332***
Value/Understanding of statistical evidence	3.260 (0.033)	3.503 (0.035)	3.972 (0.047)	-0.244***	-0.712***	-0.468***
F-test of joint significance (F-stat)				52.297***	97.001***	25.024***
F-test, number of observations				1,756	1,573	961

Notes: Variables are binary indicators, except for Trust in scientists, Trust in politicians and Value/Understanding of anecdotal/statistical evidence, which were measured on a 1-7 point Likert scale, with higher values indicating higher trust/self-rated ability. Class assignment is definite and defined according to each respondents' highest predicted class probability. The resulting class assignment is captured in a categorical variable with three categories. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

3.2 Survey experiment: Average effects of communicator and evidence type

We briefly report the average treatment effects of the tested communication strategies in the entire sample and then examine possible heterogeneous effectiveness in terms of communicator and evidence type for the identified classes. In all of the results reported here, the dependent variable is respondents' willingness to get vaccinated with the new hypothetical COVID-19 vaccine[10].

Table 2 presents the estimation results for average treatment effects. First, the coefficient of scientists as communicators is statistically significant and positive in both estimations (Columns (1) and (2)), suggesting that scientists were on average more persuasive as communicators than politicians. Employing scientists as the communicator relatively increased the reported willingness to get vaccinated on average by approximately 0.184 standard deviations.

Second, the insignificant coefficients of both evidence types in Columns (3) and (4) suggest that

[10] All models are estimated using OLS regressions. To account for the ordered scale of the dependent variable, we report results of ordered logit estimations in the Appendix.

neither the provision of statistical nor anecdotal evidence on average increased the persuasiveness of information about the efficacy of a COVID-19 vaccine.

Third, Columns (5) and (6) and the t-tests at the bottom of the table report the results for examining the interaction between both treatments, indicating which type of evidence was the most persuasive communication strategy for each communicator. For politicians, we found no significant difference between no evidence (reference category), anecdotal evidence, and statistical evidence. For scientists, t-tests on the point estimates also revealed no significant differences between the three types of evidence. Hence, neither for politicians nor scientists does it seem to matter whether and what form of evidence they use when informing the average unvaccinated public about the efficacy of COVID-19 vaccines.

Table 2
Treatment Effects of Evidence Type and Communicator on Vaccination Intentions.

	(1)	(2)	(3)	(4)	(5)	(6)
Politician	Reference category					
Scientist	0.184^{**}	0.185^{**}				
	(2.32)	(2.34)				
No Evidence			Reference category			
Anecdotal Evidence			0.137	0.153		
			(1.41)	(1.57)		
Statistical Evidence			0.0354	0.0477		
			(0.36)	(0.49)		
No Evidence Politicians					Reference category	
Anecdotal Evidence Politicians					0.204	0.209
					(1.49)	(1.53)
Statistical Evidence Politicians					0.143	0.159
					(1.04)	(1.16)
No Evidence Scientists					0.300^{**}	0.297^{**}
					(2.18)	(2.16)
Anecdotal Evidence Scientists					0.372^{***}	0.395^{***}
					(2.70)	(2.88)
Statistical Evidence Scientists					0.228^{*}	0.234^{*}
					(1.66)	(1.70)
Ex post t-tests (t-values):						
No Evidence Scientists vs. Anecdotal Evidence Scientists					0.28	0.50
No Evidence Scientists vs. Statistical Evidence Scientists					0.27	0.21
Anecdotal Evidence Scientists vs. Statistical Evidence Scientists					1.09	1.37
Socioeconomic Controls	No	Yes	No	Yes	No	Yes
Observations	2142	2141	2142	2141	2142	2141

Notes: The table shows standardized regression coefficients. Estimations in Columns (2), (4), and (6) include controls for age, gender, level of education, state of residency, and level of income. t statistics in parentheses. *, **, *** indicate significance at the 1, 5, and 10 percent critical level

These results suggest that while scientists, on average, are more persuasive communicators, the type of evidence seems to be largely irrelevant for the success of communication strategies in the average sample population.

3.3 Survey experiment: Heterogeneity by classes of vaccination hesitancy

We now turn to potentially varying effects of the explored treatments due to respondents' differential elaboration likelihood, as reflected in the identified classes of vaccination *opponents*, *sceptics*, and *receptives*. The results of this exercise are presented in Figures 3 and 4, and we discuss them in turn for each class separately.

Opponents

For vaccination *opponents*, the results in Figure 3 show that neither the communicator nor the provision and type of evidence seems to be crucial for the persuasiveness of the information about COVID-19 vaccine efficacy. In accordance with this, the results in Figure 4 suggest no clear communication strategy for politicians and scientists to target vaccination *opponents*: for both communicators, there are no significant differences between the evidence types.

Sceptics

For *sceptics*, the results are more unequivocal. First, concerning the communicator, Column (2) row 2 of Figure 3 shows that the coefficient for scientists is 0.2 standard deviations higher than for politicians. This difference is statistically significant (average p-value[11]: 0.023). This comparatively strong effect suggests that it may be the subgroup of *sceptics* which drives the effect found for the average population.

Second, we observe that, for *sceptics*, also the provision of evidence about the efficacy of the COVID-19 vaccine does seem to matter: Compared to the no evidence condition, both anecdotal evidence and statistical evidence have a positive and statistically significant effect (average p-value: 0.006 for anecdotal evidence and 0.019 for statistical evidence). *Sceptics* seem, however, not to differentiate between the evidence type since we found no statistically significant difference between anecdotal and statistical evidence.

Third, in terms of the explored interaction between communicator and evidence type, the results in Figure 4 reveal that scientists can especially enhance the persuasiveness of their conveyed information by providing additional evidence (average p-value anecdotal evidence: 0.012; average p-value statistical evidence: 0.043). While anecdotal evidence seems to be most promising in this regard, the effects are again not significantly different from when providing statistical evidence (average p-value: 0.574).

Receptives

For the group with the highest willingness to get vaccinated, the results reveal no statistically significant differences between communicators and the evidence types.

[11] We report average p-values as our estimations are based on 1,000 simulations of Equation 1 with a probabilistic assignment of respondents to the respective classes.

Interestingly, however, the results in Figure 4 suggest that politicians providing statistical evidence offer the most promising communication strategy (average p-value: 0.010; reference group are politicians without any evidence). This is surprising because, on average, neither politicians nor statistical evidence had a statistically significant effect on respondents' reported vaccination intentions.

In sum, the above findings reveal notably different patterns across the three identified classes of vaccination hesitancy and point towards promising communication strategies, especially for *sceptics* and *receptives*. These insights had not been visible by just exploring average effects. Moreover, the statistically significant subgroup effects are substantially larger in magnitude, ranging from 0.38 (politicians addressing *receptives* based on statistical evidence) to 0.45 standard deviations (scientists addressing *sceptics* based on anecdotal evidence). This is supportive evidence suggesting that the different groups of vaccination hesitant respondents indeed express different elaboration likelihoods depending on the here explored communication strategies[12].

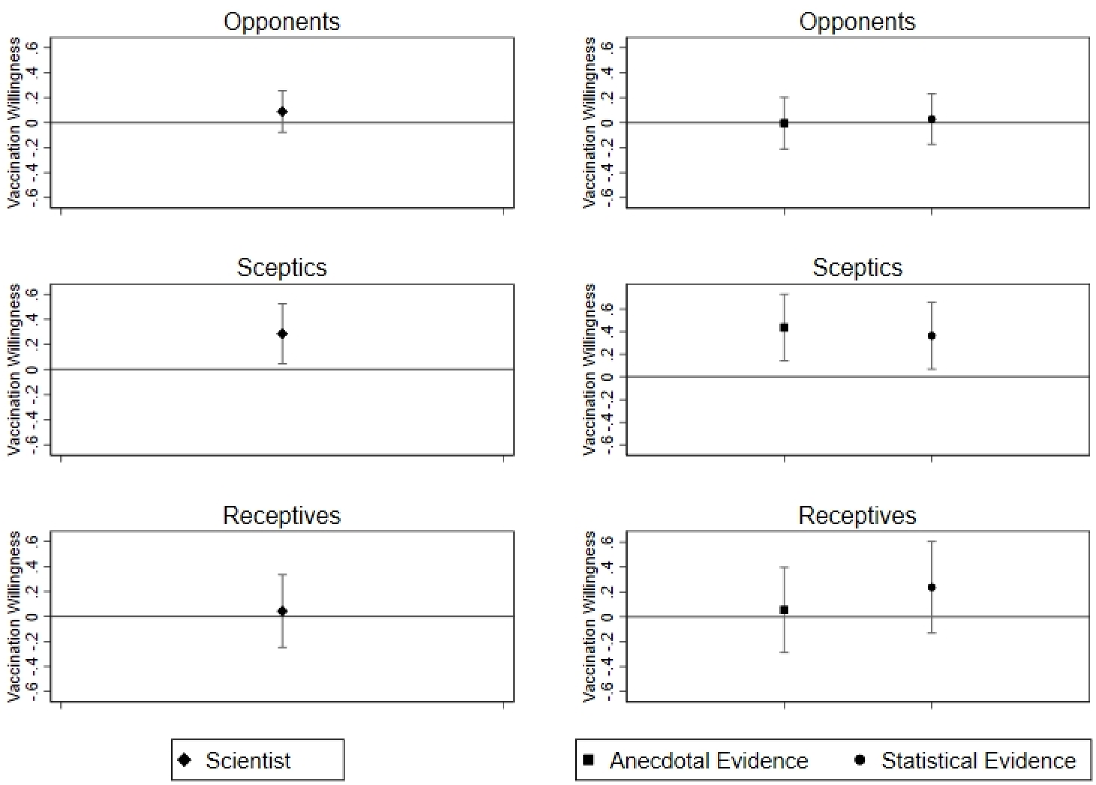

Fig. 3. Heterogeneity by Class: Separate Treatment Effects of Evidence Type and Communicator on Vaccination Intentions. *Notes:* The figure shows the mean estimation coefficient and 95% confidence intervals of 1,000 simulations for each of the three classes of vaccination hesitancy. Class assignment for each respondent is based on the class membership probability, which is derived from the LCA. The left column shows treatment effects for evidence type with the reference category "no evidence." The right column shows the treatment effects of the communicator, with the reference category "Politician". Estimations include controls for age, gender, education level, state of residency, and income level. Detailed estimation results are available in Table A11 in Appendix B.

[12] Appendix A and Figures A2 to A4 contain additional analyses that analyze whether the reported effects are due to class differences in (i) perceptions of the credibility of the information, (ii) the relevance of the information for one's reported intention to get vaccinated, and (iii) the credibility of the information source.

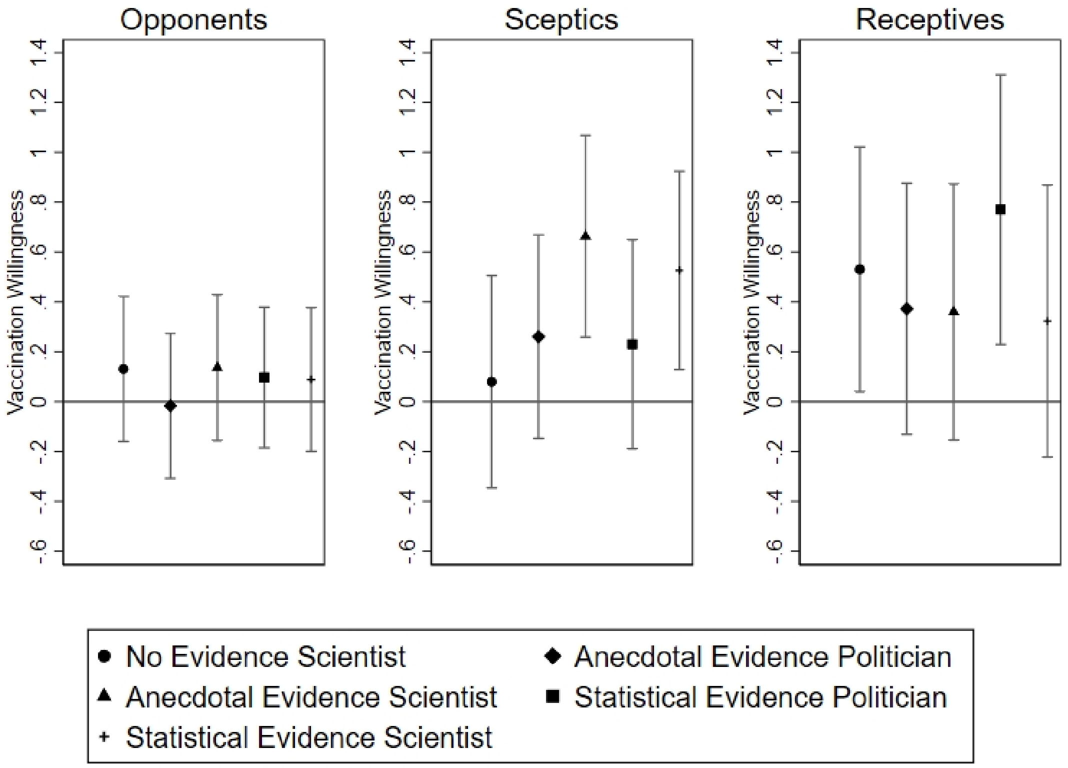

Fig. 4. Heterogeneity by Class: Interacted Treatment Effects of Communicator-Evidence Combinations on Vaccination Intentions. *Notes:* The figure shows mean treatment effects and 95% confidence intervals of 1,000 simulations for each of the three classes of vaccination hesitancy. The reference category is "No Evidence Politicians." Class assignment for each respondent is based on the class membership probability, which is derived from the LCA. Estimations include controls for age, gender, education level, state of residency, and income level. Detailed estimation results are available in Table A12 in Appendix B.

4 Conclusion

Despite soaring case numbers and a sufficient supply of vaccination doses at their disposal, policy makers in several countries in the Global North have been struggling with motivating their unvaccinated population strata. Against this background, we investigated how to persuasively communicate information about the efficacy of a COVID-19 vaccination to this population group. This paper presented evidence from an original online survey with a sample of more than 2,000 unvaccinated individuals in Germany designed to (i) examine their characteristics in more detail and (ii) assess in an experimental setting how to best communicate information about vaccine efficacy to meet their needs and concerns.

A latent class analysis points towards the existence of three distinct subgroups within the sample of unvaccinated respondents: *opponents*, *sceptics*, *receptives*. Guided by the theoretical framework of the ELM, we analyzed their intentions and beliefs and assessed how they respond to varying communicators and types of evidence in a survey experiment, which provided respondents with information about the efficacy of a COVID-19 vaccination. On average, scientists were the more persuasive information communicators - the additional provision of evidence underpinning the information about vaccine efficacy, on the other hand, seemed to be less important. However, there seem to exist significant heterogeneities across the identified subgroups.

While vaccination *opponents* seem very difficult to target, our findings suggest potentially fruitful combinations of communicators and evidence types for the other two subgroups. Specifically, anecdotal (statistical) evidence provided by scientists (politicians) was found to be promising a communication strategy to encourage vaccination intentions in the subgroup of *sceptics* (*receptives*). For the case of *sceptics*, one potential explanation for this somewhat unexpected result could be that scientists are already perceived as highly credible. While anecdotal evidence may decrease the perceived distance towards laypeople, the additional credibility gains from statistical evidence are limited. Thus, providing communicator-evidence combinations that are less present in the public debate could prove particularly effective. Overall effect sizes of increases in vaccination intentions ranged from 0.1 to 0.45 standard deviation, which may tip the scales for vaccine *sceptics* and *receptives*.

These insights suggest that, in the short term, *receptives* and *sceptics* are the most promising target groups for German vaccination campaigns (which could be achieved by considering the subgroups' characteristics in terms of gender, education, and residency). Yet, in the medium term, *opponents* need not be forgotten. While mandatory vaccinations (Graeber et al., 2021; Hirani, 2021) may appear as the only strategy to target strict vaccination *opponents* - characterized by low trust in established societal actors and less motivation to engage with the context - politicians and researchers are advised to focus on ways how to rebuild trust within this population group, not only in Germany (Lazarus et al., 2021; Schernhammer et al., 2021). Addressing this question might be key to weather the next waves of the pandemic and motivate an avenue for future research. Moreover, further studies may want to examine the relevance of the provided information more closely - a factor that might increase the persuasiveness of information campaigns. Specifically, in this paper, we examined an information treatment about COVID-19 hospitalization risk, but it might be that information and evidence on the infection probability or the risk of long-COVID have a higher relevance. Future research may include such different types of information to reveal other promising combinations of communicator-evidence strategies for the identified subgroups of vaccination hesitancy.

On a more general note, this paper contributes to a recent and highly relevant policy issue by challenging the view of a single homogeneous group of unvaccinated citizens. It thereby encourages decision-makers to carefully consider heterogeneities in the effectiveness of their communication strategies, especially about their communicator and employed evidence type. Thus, instead of suggesting a one-size-fits-all approach, we understand our research as a stepping-stone to identifying (i) heterogeneities in vaccination hesitancy and (ii) derive promising communicator-evidence combinations across settings and based on theoretical considerations.

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Appendix A

Pre-Analysis Plan deviations and rationale

We deviate from the Pre-Analysis Plan in 3 specific points. First, we do not examine how additional evidence affects the perceived effectiveness of vaccines (see H4 Pre-Analysis Plan). Perceived vaccine effectiveness is arguably a critical outcome of vaccine information campaigns. However, we believe that it has more of a mediating function in framing individuals' vaccination hesitancy. Second, we do not examine the ELM-specific hypotheses (H6-H6b Pre-Analysis Plan). We deliberately deviate from the Pre-Analysis Plan here because we perceive the heterogeneity of effects across the different classes of vaccination hesitancy to be more relevant for policymakers by allowing for more concrete policy recommendations. Finally, for the sake of conciseness, we do not examine hypotheses H7a (Trust), H8 (Conspiracy), and H10 (Gender). However, we elaborate on this when examining characteristics of the three classes (i.e., regarding trust, gender, and conspiracy beliefs).

Data collection procedures

We relied on a sample of respondents from Germany who did not yet receive their first dose of the vaccine[13]. Respondents have been recruited from a German access panel maintained by the survey company 'respondi' and data has been collected via "Qualtrics" software. 'Respondi' has incentivized participation with mingle points worth approx. one Euro , which respondents could redeem in the form of cash, vouchers, or donations.

Sample size

Power calculations based on Argote et al. (2021) and Haase et al. (2020) revealed that a number of N= 232 - 356 respondents per trialarm would allow to detect significant treatment effects of the corresponding magnitude (d = 0.5) with a statistical power of 80 percent (and $\alpha = 0.05$). The factorial design yields three (evidence type) x two (communicator) = six trialarms. Thus, we aimed for a total sample size of 2,200 respondents and stopped recruiting once this number was reached. Financial and target population accessibility constraints did not allow us to include a higher number than the number which we calculated in the power analysis.

Information treatment

We consider the following information treatments to assess the effects of evidence type (anecdotal, statistical, or no evidence at all) and communicator identity (politician or scientist).

[13] Due to feasibility constraints, it was not possible to use quota sampling, given the German vaccine prioritization scheme based on age, as well as the very specific target population of vaccination hesitant individuals, who may itself be related to acquired quotas such as e.g. education or gender. Instead, we aim for a broad sample spread in terms of respondents' age, gender, education and state of residence.

Groups A, B, and C: intro treatment:

With a current R-value that is greater than 1, COVID-19 infection figures in Germany are rising again (that is, one infected person infects on average more than one other person). At the same time, the incidence level amounts to approximately 50 infected persons per 100,000 persons. [Date: August 20, 2021[14]].

Group A - No Evidence:

Now imagine that a new COVID-19 vaccine has been developed and approved. Isabel Sommer [*politician/scientist*] talks about a promising vaccine that reduces hospitalizations due to COVID-19[15].

Group B - Anecdotal evidence:

Now imagine that a new COVID-19 vaccine has been developed and approved. Isabel Sommer ([politician/scientist]) talks about a promising vaccine that reduces hospitalizations due to COVID-19. The [*politician/scientist*] reports a hospital visit in a city where this vaccine is currently in use: "I have hardly encountered a vaccinated person here who currently needs treatment for COVID-19 infection - among the patients are almost exclusively non-vaccinated persons."[16].

Group C - Statistical evidence:

Now imagine that a new COVID-19 vaccine has been developed and approved. Isabel Sommer [*politician/scientist*] talks about a promising vaccine that reduces hospitalizations due to COVID-19. The [*politician/scientist*] cites clinical trials. These show that non-vaccinated persons have a 96% higher risk of hospitalization due to the COVID-19 infection compared to vaccinated persons[17].

Uncertainty in LCA Models

In general three methods have been proposed to deal with uncertainty in LCA. First, assigning latent classes based on modal posterior probability of membership and treating them as fixed and known (Bakk et al., 2013). Second, making assignments based on posterior modal values,

[14] German wording: Mit einem aktuellen R-Wert, der größer als 1 ist, steigen die COVID-19 Infektionszahlen in Deutschland zurzeit wieder an, d.h. eine infizierte Person steckt im Schnitt mehr als eine weitere Person an. Gleichzeitig liegt der Inzidenzwert bei ca. 50 Infizierten unter 100.000 Personen. Stand: 20. August, 2021

[15] German wording: Stellen Sie sich nun vor, es wurde ein neuer COVID-19-Impfstoff entwickelt und zugelassen. Isabel Sommer (Politikerin/Wissenschaftlerin) spricht von einem vielversprechenden Impfstoff, der Krankenhausaufenthalte aufgrund von COVID-19 reduziert.

[16] German wording: Stellen Sie sich nun vor, es wurde ein neuer COVID-19-Impfstoff entwickelt und zugelassen. Isabel Sommer ([Politikerin/Wissenschaftlerin]) spricht von einem vielversprechenden Impfstoff, der Krankenhausaufenthalte aufgrund von COVID-19 reduziert. Die [Politikerin/Wissenschaftlerin] berichtet von einem Krankenhausbesuch in einer Stadt, in der dieser Impfstoff aktuell genutzt wird: „Ich habe hier kaum eine geimpfte Person angetroffen, die aktuell aufgrund einer COVID-19-Erkrankung behandelt werden muss - unter den Patienten sind fast ausschließlich Nicht-Geimpfte.“

[17] German wording: Stellen Sie sich nun vor, es wurde ein neuer COVID-19-Impfstoff entwickelt und zugelassen. Isabel Sommer ([Politikerin/Wissenschaftlerin]) spricht von einem vielversprechenden Impfstoff, der Krankenhausaufenthalte aufgrund von COVID-19 reduziert. Die [Politikerin/Wissenschaftlerin] beruft sich dabei auf klinische Studien. Diese zeigen, dass Nicht-Geimpfte ein 96% höheres Risiko eines Krankenhausaufenthalts aufgrund einer COVID-19 Erkrankung haben, verglichen mit geimpften Personen.

but then using a weighted likelihood method with weights given by an entropy measure of the correct probability of classification (Collins and Lanza, 2009). Third, a multiple imputation approach based on repeated imputations of the latent class based on the vector of their posterior probabilities of class assignment (Roeder et al., 1999).

Mediation analysis: Why is some information more persuasive than other

To elicit potential mechanisms, we investigated whether the perceptions on relevance and credibility of communicators and evidence vary across groups. To this end, we examined whether (1) perceptions of the credibility of the provided information, (2) the relevance of the information for one's reported intention to get vaccinated, and (3) the credibility of the information source vary across the identified classes of unvaccinated (see Figures A2-A4 in Appendix B).

In line with the theoretical framework of the ELM, our results suggest that the persuasiveness of messages does depend to a large degree on the perceived credibility and relevance of the information. However, both factors are not a guarantee for high persuasiveness.

Figure A2 indicates that both *opponents* and *sceptics* perceive scientists themselves, but also information by scientists as more credible than information from politicians (average p-value *opponents*: 0.000; average p-value *sceptics*: 0.037). Additionally, *opponents* seem to perceive information provided by scientists as more relevant for their vaccination decision than information by politicians.

Interestingly, our previous results have shown that, for *opponents*, unlike for *sceptics*, the persuasiveness of information provided by scientists is not higher compared to information provided by politicians. Although *opponents* perceive information by scientists as credible and relevant, they are not persuaded by the provided information. These results suggest that communicator credibility - in line with the ELM - is an important, but not yet sufficient factor for persuasive messages.

With regards to evidence, *opponents* seem to perceive anecdotal evidence as most credible (average p-value: 0.057), but at the same time least relevant to their vaccination decision (Figure A3). Interestingly, for the group of *receptives*, exactly the opposite is true. This group perceives statistical evidence as most credible, but not as significantly more relevant to their vaccination decision. Thus, *opponents* and *receptives* perceive the credibility of anecdotal and statistical evidence differently, which corresponds once more to the theoretical expectations of the ELM. However, findings may also suggest that the provided information (about high numbers of unvaccinated relying on treatment in intensive care units) is perceived as having little relevance to one's vaccination decision (as evidenced also by the lack of significant effects on relevance in Figure A3. Thus, if the relevance of information can be improved, the persuasiveness might increase as well.

Appendix B

Table A1
Sample Characteristics.

Variable	Values/Description	Mean (SD)	Min	Max	N
Female	0: male (36.09%) 1: female (63.91%)	0.639 (0.480)	0	1	2,142
Age group	1: 18-34 yrs. (32.07%) 2: 35-54 yrs. (50.35%) 3: 55 yrs. and above (17.58%)	1.855 (0.690)	1	3	2,145
Education	1: low (14.53%) 2: medium (35.80%) 3: high (49.67%)	2.352 (0.720)	1	3	2,134
Residence in new fed. states	0: No (74.92%) 1: Yes (25.08%)	0.251 (0.434)	0	1	2,134
Vaccination willingness (hyp. vaccine)	Willingness to get vaccinated next week if given the offer, Likert 1-7	2.685 (1.838)	1	7	2,142
Confidence (item 1)	5C scale by Betsch et al. (2018), see Table A12 for exact wording, Likert 1-7	3.088 (1.784)	1	7	2,143
Confidence (item 2)	5C scale by Betsch et al. (2018), see Table A12 for exact wording, Likert 1-7	2.286 (1.737)	1	7	2,143
Confidence (item 3)	5C scale by Betsch et al. (2018), see Table A12 for exact wording, Likert 1-7	2.557 (1.804)	1	7	2,142
Complacency (item 1)	5C scale by Betsch et al. (2018), see Table A12 for exact wording, Likert 1-7	4.275 (1.876)	1	7	2,143
Complacency (item 2)	5C scale by Betsch et al. (2018), see Table A12 for exact wording, Likert 1-7	3.226 (1.818)	1	7	2,142
Complacency (item 3)	5C scale by Betsch et al. (2018), see Table A12 for exact wording, Likert 1-7	4.173 (2.026)	1	7	2,143
Coll. responsibility (item 1)	5C scale by Betsch et al. (2018), see Table A12 for exact wording, Likert 1-7	3.683 (2.037)	1	7	2,142
Coll. responsibility (item 2)	5C scale by Betsch et al. (2018), see Table A12 for exact wording, Likert 1-7	2.839 (1.996)	1	7	2,142
Coll. responsibility (item 3)	5C scale by Betsch et al. (2018), see Table A12 for exact wording, Likert 1-7	3.381 (2.049)	1	7	2,142
Calculation (item 1)	5C scale by Betsch et al. (2018), see Table A12 for exact wording, Likert 1-7	5.982 (1.562)	1	7	2,142
Calculation (item 2)	5C scale by Betsch et al. (2018), see Table A12 for exact wording, Likert 1-7	5.674 (1.584)	1	7	2,141
Calculation (item 3)	5C scale by Betsch et al. (2018), see Table A12 for exact wording, Likert 1-7	5.830 (1.573)	1	7	2,143
Constraints (item 1)	5C scale by Betsch et al. (2018), see Table A12 for exact wording, Likert 1-7	2.501 (1.809)	1	7	2,142
Constraints (item 2)	5C scale by Betsch et al. (2018), see Table A12 for exact wording, Likert 1-7	2.474 (1.837)	1	7	2,142
Constraints (item 3)	5C scale by Betsch et al. (2018), see Table A12 for exact wording, Likert 1-7	2.183 (1.707)	1	7	2,143
Trust in scientists	Confidence in scientists to properly handle the pandemic, Likert 1-7	4.182 (1.616)	1	7	2,145
Trust in politicians	Confidence in politicians to properly handle the pandemic, Likert 1-7	2.343 (1.536)	1	7	2,145
Perceived value of anecdotal evidence	Value of personal experiences as evidence, Likert 1-5	3.536 (0.989)	1	5	2,145
Perceived value of statistical evidence	Value of statistics as evidence, Likert 1-5	3.454 (1.052)	1	5	2,144

Table A2
Overview Latent Class and Latent Profile Analysis.

Latent Class Analysis			
Log likelihood:	-24229.93		
Likelihood ratio:	18217.163, p>chi2 = 1.00		
AIC:	48643.86		
BIC:	49165.54		
Class	Marginal class probability	Std. Error	95% CI
Opponents	0.5514	0.0127	[0.5264;0.5761]
Sceptics	0.1824	0.0098	[0.1639;0.2024]
Receptives	0.2663	0.0125	[0.2426;0.2914]
Latent profile analysis			
Log likelihood:	-59678.93		
Likelihood ratio:	-		
AIC:	119481.85		
BIC:	119833.42		
Class	Marginal class probability	Std. Error	95% CI
Opponents	0.4196	0.0138	[0.3928;0.4469]
Sceptics	0.3358	0.0126	[0.3116;0.3609]
Receptives	0.2446	0.0104	[0.2248;0.2655]

Table A3
Opponents Class (LCA): Marginal Predicted Means (Reflective Indicators).

Indicator (5Cs)	Margin	Std. Error	95% CI
Confidence (item 1)			
value=1	0.702	0.015	[0.672;0.730]
value=2	0.287	0.014	[0.260;0.316]
value=3	0.011	0.003	[0.006;0.020]
Confidence (item 2)			
value=1	0.972	0.006	[0.958;0.981]
value=2	0.025	0.005	[0.016;0.038]
value=3	0.004	0.002	[0.001;0.010]
Confidence (item 3)			
value=1	0.903	0.010	[0.882;0.921]
value=2	0.092	0.010	[0.074;0.112]
value=3	0.005	0.002	[0.002;0.012]
Complacency (item 1)			
value=1	0.114	0.010	[0.096;0.135]
value=2	0.462	0.015	[0.432;0.492]
value=3	0.424	0.015	[0.395;0.453]
Complacency (item 2)			
value=1	0.314	0.014	[0.288;0.342]
value=2	0.508	0.015	[0.478;0.537]
value=3	0.178	0.011	[0.157;0.201]
Complacency (item 3)			
value=1	0.125	0.010	[0.107;0.147]
value=2	0.406	0.015	[0.376;0.436]
value=3	0.469	0.015	[0.439;0.499]
Col. responsibility (item 1)			
value=1	0.279	0.013	[0.254;0.307]
value=2	0.421	0.015	[0.392;0.451]
value=3	0.299	0.014	[0.273;0.327]
Col. responsibility (item 2)			
value=1	0.871	0.012	[0.846;0.893]
value=2	0.121	0.012	[0.100;0.146]
value=3	0.008	0.003	[0.004;0.016]
Col. responsibility (item 3)			
value=1	0.677	0.015	[0.647;0.706]
value=2	0.293	0.015	[0.265;0.322]
value=3	0.030	0.005	[0.021;0.042]
Constraints (item 1)			
value=1	0.761	0.013	[0.735;0.785]
value=2	0.175	0.011	[0.154;0.199]
value=3	0.064	0.007	[0.051;0.079]
Constraints (item 2)			
value=1	0.730	0.013	[0.703;0.755]
value=2	0.193	0.012	[0.171;0.217]
value=3	0.077	0.008	[0.063;0.094]
Constraints (item 3)			
value=1	0.874	0.010	[0.853;0.893]
value=2	0.091	0.009	[0.075;0.110]
value=3	0.035	0.005	[0.025;0.047]
Calculation (item 1)			
value=1	0.045	0.006	[0.034;0.058]
value=2	0.054	0.007	[0.042;0.070]
value=3	0.901	0.009	[0.882;0.917]
Calculation (item 2)			
value=1	0.074	0.008	[0.061;0.091]
value=2	0.207	0.012	[0.184;0.232]
value=3	0.718	0.013	[0.691;0.744]
Calculation (item 3)			
value=1	0.060	0.007	[0.048;0.076]
value=2	0.124	0.010	[0.106;0.146]
value=3	0.816	0.012	[0.791;0.838]
Prevalence in sample (N=2,144)		55.14%	

Notes: Shown are marginal means, standard errors and 95% CIs for the latent class 'Opponents' identified through a latent class analysis (LCA). Indicators of the LPA were the 15 items from the 5C scale on COVID-19 vaccine hesitancy. While we initially measured agreement with the presented items on a 7 point Likert scale, we had to condense the scale into three categories due to skewed and non-normally distributed data, not allowing the model to converge. The three condensed categories combined the two extreme points of the initial Likert scale as well as the three moderate points (initial values 1 or 2 ⇒ condensed value 1; initial values 3,4 or 5 ⇒ condensed value 2; initial values 6 or 7 ⇒ condensed value 3). This results in ordinal variables with three categories, which were then used as categorical indicators for the LCA (the marginal means presented here are thus in categorical form, for each of the three categories separately). The initial 7-point Likert scale and the condensed scale are on average across all 15 items highly correlated by a value of approximately 0.95.

Table A4
Sceptics Class (LCA): Marginal Predicted Means (Reflective Indicators).

Indicator (5Cs)	Margin	Std. Error	95% CI
Confidence (item 1)			
value=1	0.124	0.015	[0.097;0.157]
value=2	0.839	0.017	[0.803;0.869]
value=3	0.037	0.008	[0.024;0.058]
Confidence (item 2)			
value=1	0.377	0.024	[0.332;0.425]
value=2	0.582768	0.024	[0.536;0.628]
value=3	0.040	0.009	[0.026;0.061]
Confidence (item 3)			
value=1	0.221	0.021	[0.184;0.265]
value=2	0.739	0.021	[0.695;0.779]
value=3	0.040	0.009	[0.026;0.061]
Complacency (item 1)			
value=1	0.079	0.013	[0.056;0.108]
value=2	0.821	0.018	[0.783;0.853]
value=3	0.101	0.014	[0.077;0.131]
Complacency (item 2)			
value=1	0.171	0.019	[0.137;0.213]
value=2	0.811	0.020	[0.769;0.847]
value=3	0.018	0.006	[0.009;0.034]
Complacency (item 3)			
value=1	0.089	0.014	[0.065;0.121]
value=2	0.830	0.018	[0.793;0.862]
value=3	0.081	0.012	[0.061;0.108]
Col. responsibility (item 1)			
value=1	0.115	0.016	[0.086;0.149]
value=2	0.799	0.019	[0.759;0.834]
value=3	0.087	0.013	[0.065;0.115]
Col. responsibility (item 2)			
value=1	0.121	0.016	[0.093;0.155]
value=2	0.835	0.018	[0.797;0.866]
value=3	0.045	0.009	[0.030;0.067]
Col. responsibility (item 3)			
value=1	0.067	0.012	[0.047;0.095]
value=2	0.831	0.017	[0.795;0.863]
value=3	0.102	0.014	[0.078;0.132]
Constraints (item 1)			
value=1	0.262	0.023	[0.220;0.310]
value=2	0.651	0.024	[0.603;0.697]
value=3	0.087	0.013	[0.065;0.115]
Constraints (item 2)			
value=1	0.303	0.022	[0.261;0.349]
value=2	0.625	0.023	[0.578;0.669]
value=3	0.072	0.012	[0.053;0.098]
Constraints (item 3)			
value=1	0.300	0.024	[0.256;0.349]
value=2	0.629	0.024	[0.581;0.675]
value=3	0.071	0.011	[0.052;0.097]
Calculation (item 1)			
value=1	0.020	0.006	[0.010;0.036]
value=2	0.517	0.024	[0.470;0.563]
value=3	0.464	0.024	[0.418;0.511]
Calculation (item 2)			
value=1	0.017	0.006	[0.009;0.032]
value=2	0.603	0.023	[0.558;0.647]
value=3	0.380	0.023	[0.336;0.426]
Calculation (item 3)			
value=1	0.025	0.007	[0.014;0.042]
value=2	0.593	0.023	[0.547;0.637]
value=3	0.383	0.023	[0.339;0.429]
Prevalence in sample (N=2,144)		26.63%	

Notes: Shown are marginal means, standard errors and 95% CIs for the latent class 'Sceptics' identified through a latent class analysis (LCA). Indicators of the LPA were the 15 items from the 5C scale on COVID-19 vaccine hesitancy. While we initially measured agreement with the presented items on a 7 point Likert scale, we had to condense the scale into three categories due to skewed and non-normally distributed data, not allowing the model to converge. The three condensed categories combined the two extreme points of the initial Likert scale as well as the three moderate points (initial values 1 or 2 ⇒ condensed value 1; initial values 3,4 or 5 ⇒ condensed value 2; initial values 6 or 7 ⇒ condensed value 3). This results in ordinal variables with three categories, which were then used as categorical indicators for the LCA (the marginal means presented here are thus in categorical form, for each of the three categories separately). The initial 7-point Likert scale and the condensed scale are on average across all 15 items highly correlated by a value of approximately 0.95.

Table A5

Receptives Class (LCA): Marginal Predicted Means (Reflective Indicators).

Indicator (5Cs)	Margin	Std. Error	95% CI
Confidence (item 1)			
value=1	0.040	0.012	[0.022;0.069]
value=2	0.471	0.028	[0.417;0.525]
value=3	0.490	0.028	[0.435;0.545]
Confidence (item 2)			
value=1	0.200	0.024	[0.157;0.250]
value=2	0.443	0.026	[0.392;0.495]
value=3	0.358	0.026	[0.309;0.410]
Confidence (item 3)			
value=1	0.152	0.021	[0.115;0.198]
value=2	0.458	0.026	[0.407;0.510]
value=3	0.390	0.027	[0.339;0.443]
Complacency (item 1)			
value=1	0.617	0.026	[0.564;0.667]
value=2	0.271	0.024	[0.226;0.321]
value=3	0.112	0.017	[0.083;0.150]
Complacency (item 2)			
value=1	0.898	0.018	[0.858;0.928]
value=2	0.055	0.014	[0.033;0.090]
value=3	0.047	0.011	[0.030;0.075]
Complacency (item 3)			
value=1	0.813	0.023	[0.764;0.854]
value=2	0.119	0.020	[0.085;0.164]
value=3	0.068	0.014	[0.046;0.100]
Col. responsibility (item 1)			
value=1	0.785	0.023	[0.737;0.827]
value=2	0.127	0.019	[0.094;0.169]
value=3	0.088	0.015	[0.062;0.123]
Col. responsibility (item 2)			
value=1	0.090	0.016	[0.063;0.128]
value=2	0.327	0.027	[0.276;0.381]
value=3	0.583	0.029	[0.527;0.638]
Col. responsibility (item 3)			
value=1	0.024	0.009	[0.011;0.049]
value=2	0.220	0.026	[0.174;0.275]
value=3	0.756	0.027	[0.700;0.805]
Constraints (item 1)			
value=1	0.621	0.026	[0.569;0.670]
value=2	0.227	0.022	[0.187;0.273]
value=3	0.152	0.019	[0.119;0.193]
Constraints (item 2)			
value=1	0.719	0.024	[0.669;0.764]
value=2	0.178	0.021	[0.141;0.223]
value=3	0.103	0.016	[0.076;0.139]
Constraints (item 3)			
value=1	0.688	0.025	[0.638;0.734]
value=2	0.187	0.021	[0.150;0.231]
value=3	0.125	0.018	[0.094;0.163]
Calculation (item 1)			
value=1	0.128	0.0174	[0.098;0.166]
value=2	0.279	0.024	[0.235;0.327]
value=3	0.593	0.026	[0.541;0.643]
Calculation (item 2)			
value=1	0.040	0.010	[0.024;0.065]
value=2	0.276	0.024	[0.232;0.324]
value=3	0.685	0.025	[0.635;0.731]
Calculation (item 3)			
value=1	0.081	0.014	[0.058;0.114]
value=2	0.233	0.023	[0.192;0.280]
value=3	0.686	0.025	[0.636;0.732]
Prevalence in sample (N=2,144)		18.24%	

Notes: Shown are marginal means, standard errors and 95% CIs for the latent class 'Receptives' identified through a latent class analysis (LCA). Indicators of the LPA were the 15 items from the 5C scale on COVID-19 vaccine hesitancy. While we initially measured agreement with the presented items on a 7 point Likert scale, we had to condense the scale into three categories due to skewed and non-normally distributed data, not allowing the model to converge. The three condensed categories combined the two extreme points of the initial Likert scale as well as the three moderate points (initial values 1 or 2 ⇒ condensed value 1; initial values 3,4 or 5 ⇒ condensed value 2; initial values 6 or 7 ⇒ condensed value 3). This results in ordinal variables with three categories, which were then used as categorical indicators for the LCA (the marginal means presented here are thus in categorical form, for each of the three categories separately). The initial 7-point Likert scale and the condensed scale are on average across all 15 items highly correlated by a value of approximately 0.95.

Table A6
Opponents Class (LPA): Marginal Predicted Means (Reflective Indicators).

Indicator (5Cs)	Margin	Std. Error	95% CI
Confidence (item 1)	1.682	0.045	[1.593;1.771]
Confidence (item 2)	1.123	0.031	[1.063;1.183]
Confidence (item 3)	1.268	0.040	[1.189;1.346]
Complacency (item 1)	5.354	0.068	[5.220;5.487]
Complacency (item 2)	4.047	0.066	[3.917;4.177]
Complacency (item 3)	5.518	0.071	[5.379;5.656]
Col. responsibility (item 1)	3.666	0.071	[3.527;3.806]
Col. responsibility (item 2)	1.254	0.043	[1.170;1.338]
Col. responsibility (item 3)	1.674	0.052	[1.572;1.775]
Constraints (item 1)	1.991	0.061	[1.872;2.110]
Constraints (item 2)	2.119	0.063	[1.996;2.242]
Constraints (item 3)	1.549	0.055	[1.441;1.657]
Calculation (item 1)	6.512	0.052	[6.411;6.613]
Calculation (item 2)	5.833	0.055	[5.726;5.941]
Calculation (item 3)	6.200	0.054	[6.094;6.306]
Prevalence in sample (N=2,144)		41.96%	

Notes: Shown are marginal means, standard errors and 95% CIs for the latent class 'Opponents' identified through a latent profile analysis (LPA). Indicators of the LPA were the 15 items from the 5C scale on COVID-19 vaccine hesitancy, each measured on a 1-7 Likert scale and assumed to serve as continuous indicators for the LPA.

Table A7
Sceptics Class (LPA): Marginal Predicted Means (Reflective Indicators).

Indicator (5Cs)	Margin	Std. Error	95% CI
Confidence (item 1)	3.403	0.057	[3.291;3.515]
Confidence (item 2)	1.875	0.050	[1.780;1.971]
Confidence (item 3)	2.504	0.060	[2.387;2.622]
Complacency (item 1)	3.643	0.068	[3.510;3.776]
Complacency (item 2)	2.631	0.068	[2.498;2.764]
Complacency (item 3)	3.441	0.069	[3.305;3.577]
Col. responsibility (item 1)	4.576	0.079	[4.422;4.731]
Col. responsibility (item 2)	3.038	0.068	[2.905;3.171]
Col. responsibility (item 3)	3.970	0.067	[3.840;4.101]
Constraints (item 1)	2.517	0.073	[2.373;2.661]
Constraints (item 2)	2.532	0.074	[2.386;2.678]
Constraints (item 3)	2.246	0.070	[2.108;2.384]
Calculation (item 1)	6.059	0.059	[5.943;6.175]
Calculation (item 2)	5.774	0.064	[5.649;5.899]
Calculation (item 3)	5.862	0.063	[5.740;5.985]
Prevalence in sample (N=2,144)		33.58%	

Notes: Shown are marginal means, standard errors and 95% CIs for the latent class 'Sceptics' identified through a latent profile analysis (LPA). Indicators of the LPA were the 15 items from the 5C scale on COVID-19 vaccine hesitancy, each measured on a 1-7 Likert scale and assumed to serve as continuous indicators for the LPA.

Table A8
Receptives Class (LPA): Marginal Predicted Means (Reflective Indicators).

Indicator (5Cs)	Margin	Std. Error	95% CI
Confidence (item 1)	5.066	0.055	[4.958;5.174]
Confidence (item 2)	4.844	0.048	[4.749;4.939]
Confidence (item 3)	4.839	0.054	[4.733;4.950]
Complacency (item 1)	3.294	0.073	[3.150;3.437]
Complacency (item 2)	2.636	0.075	[2.489;2.783]
Complacency (item 3)	2.871	0.075	[2.725;3.017]
Col. responsibility (item 1)	5.079	0.087	[4.908;5.250]
Col. responsibility (item 2)	5.287	0.059	[5.172;5.402]
Col. responsibility (item 3)	5.499	0.063	[5.375;5.623]
Constraints (item 1)	3.353	0.077	[3.202;3.505]
Constraints (item 2)	3.004	0.080	[2.847;3.162]
Constraints (item 3)	3.182	0.0715	[3.042;3.322]
Calculation (item 1)	4.968	0.065	[4.841;5.096]
Calculation (item 2)	5.266	0.070	[5.129;5.403]
Calculation (item 3)	5.152	0.068	[5.020;5.285]
Prevalence in sample (N=2,144)		24.46%	

Notes: Shown are marginal means, standard errors and 95% CIs for the latent class 'Receptives' identified through a latent profile analysis (LPA). Indicators of the LPA were the 15 items from the 5C scale on COVID-19 vaccine hesitancy, each measured on a 1-7 Likert scale and assumed to serve as continuous indicators for the LPA.

Table A9
Vaccination Willingness by Class.

Variable	(1) Opponents (N=1,184)	(2) Sceptics (N=572)	(3) Receptives (N=389)	(1)-(2)	T-test Difference (1)-(3)	(2)-(3)
Willingness (hypothetical vaccine)	1.732	3.428	4.495	-1.696***	-2.763***	-1.068***
	(0.036)	(0.061)	(0.102)			
Willingness (BioNTech Pfizer)	1.913	4.086	5.771	-2.173***	-3.858***	-1.686***
	(0.044)	(0.071)	(0.081)			
Willingness (Moderna)	1.733	3.654	4.925	-1.921***	-3.192***	-1.272***
	(0.039)	(0.068)	(0.093)			
Willingness (AstraZeneca)	1.329	2.488	2.941	-1.158***	-1.611***	-0.453***
	(0.026)	(0.067)	(0.107)			
Willingness (Johnson & Johnson)	1.734	3.206	4.064	-1.472***	-2.330***	-0.858***
	(0.039)	(0.069)	(0.105)			
Willingness (Sputnik V)	1.846	2.836	2.823	-0.989***	-0.976***	0.013
	(0.043)	(0.071)	(0.100)			
Willingness (Sinopharm)	1.634	2.728	2.975	-1.093***	-1.341***	-0.248**
	(0.036)	(0.065)	(0.091)			
F-test of joint significance (F-stat)				156.464***	328.303***	39.608***
F-test, number of observations				1756	1573	961

Notes: All variables are measured on a 7-point Likert scale, higher values indicating a higher willingness to get vaccinated. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

Table A10
Treatment Effects of Evidence Type and Communicator on Vaccination Intentions (Ordered Logit Estimation).

	(1)	(2)	(3)	(4)	(5)	(6)
Politician	Reference category					
Scientist	0.165^{**}	0.179^{**}				
	(2.07)	(2.23)				
No Evidence			Reference category			
Anecdotal Evidence			0.140	0.152		
			(1.44)	(1.55)		
Statistical Evidence			0.0459	0.0623		
			(0.47)	(0.63)		
No Evidence Politicians					Reference category	
Anecdotal Evidence Politicians					0.181	0.191
					(1.32)	(1.38)
Statistical Evidence Politicians					0.116	0.141
					(0.84)	(1.01)
No Evidence Scientists					0.240^{*}	0.260^{*}
					(1.74)	(1.86)
Anecdotal Evidence Scientists					0.339^{**}	0.369^{***}
					(2.46)	(2.66)
Statistical Evidence Scientists					0.213	0.238^{*}
					(1.55)	(1.72)
Socioeconomic Controls	No	Yes	No	Yes	No	Yes
Observations	2142	2141	2142	2141	2142	2141

Notes: The table shows regression results of an ordered logit regression. Estimations in Columns (2), (4), and (6) include controls for age, gender, level of education, state of residency, and level of income. t statistics in parentheses. *, **, *** indicate significance at the 1, 5, and 10 percent critical level

Table A11
Heterogeneity by Class: Separate Treatment Effects of Evidence Type and Communicator on Vaccination Intentions.

	(1)	(2)
Opponents	Reference category	Reference category
Sceptics	1.451*** (0.132)	1.611*** (0.106)
Receptives	2.674*** (0.144)	2.775*** (0.123)
No Evidence	Reference category	
Anecdotal Evidence	-0.006 (0.105)	
Statistical Evidence	0.029 (0.103)	
Sceptics × Anecdotal Evidence	0.438** (0.184)	
Sceptics × Statistical Evidence	0.331* (0.183)	
Receptives × Anecdotal Evidence	0.063 (0.204)	
Receptives × Statistical Evidence	0.208 (0.214)	
Politician		Reference category
Scientist		0.089 (0.085)
Sceptics × Scientist		0.201 (0.149)
Receptives × Scientist		-0.048 (0.171)
Socioeconomic Controls	Yes	Yes
Observations	2142	2141

Notes: The table shows unstandardized OLS regression coefficients. Estimations include controls for age, gender, level of education, state of residency, and level of income. t statistics in parentheses. *, **, *** indicate significance at the 1, 5, and 10 percent critical level

Table A12
Heterogeneity by Class: Interacted Treatment Effects of Communicator-Evidence Combinations on Vaccination Intentions.

	(1)
Opponents	Reference category
Sceptics	1.482*** (0.180)
Receptives	2.430*** (0.220)
No Evidence Politician	Reference category
No Evidence Scientist	0.131 (0.148)
Anecdotal Evidence Politician	-0.015 (0.148)
Anecdotal Evidence Scientist	0.138 (0.149)
Statistical Evidence Politician	0.098 (0.144)
Statistical Evidence Scientist	0.092 (0.147)
Sceptics × No Evidence Scientist	-0.054 (0.263)
Sceptics × Anecdotal Evidence Politician	0.274 (0.256)
Sceptics × Anecdotal Evidence Scientist	0.527** (0.255)
Sceptics × Statistical Evidence Politician	0.132 (0.258)
Sceptics × Statistical Evidence Scientist	0.436* (0.250)
Receptives × No Evidence Scientist	0.397 (0.291)
Receptives × Anecdotal Evidence Politician	0.388 (0.297)
Receptives × Anecdotal Evidence Scientist	0.223 (0.303)
Receptives × Statistical Evidence Politician	0.674** (0.312)
Receptives × Statistical Evidence Scientist	0.224 (0.315)
Socioeconomic Controls	Yes
Observations	2141

Notes: The table shows unstandardized OLS regression coefficients. Estimations include controls for age, gender, level of education, state of residency, and level of income. t statistics in parentheses. *, **, *** indicate significance at the 1, 5, and 10 percent critical level

Table A13 Survey Items

Variable	Item	Scale
Primary outcome variable:		
Vaccination willingness	How would you decide if you had the opportunity to be vaccinated against COVID-19 with this vaccine next week?	Scale from (1) I would definitely not get vaccinated. to (7) I would definitely get vaccinated
Secondary outcome variables (mediation analysis) :		
	Please think about the new vaccine that was the subject of some of the previous questions. Now we would like to know how you assess the information provided by Ms Sommer on this new vaccine. Please indicate to what extent you agree or disagree with the following statements:	
Credibility	The information is credible	Scale from (1) Strongly disagree to (7) Strongly agree
Relevance	The information is relevant to my decision to get vaccinated.	Scale from (1) Strongly disagree to (7) Strongly agree
Credible Source	Ms Sommer is credible as the source of the information.	Scale from (1) Strongly disagree to (7) Strongly agree

Table A13 Survey Items

Variable	Item	Scale
Independent variables:		
Education	What is your highest level of education (educational qualification)?	(1) No school-leaving qualification (2) Elementary or secondary school leaving certificate without completed apprenticeship (3) Elementary or secondary school leaving certificate with completed apprenticeship (4) Secondary school leaving certificate, Realschulabschluss (5) Advanced technical college certificate (6) Abitur (general higher education entrance qualification) (7) University of applied sciences or university degree (Bachelor, Master, Magister, Diplom or Staatsexamen) (8) Doctorate/PhD (9) Other degree:

Table A13 Survey Items

Variable	Item	Scale
Sex	What gender are you?	Female Male Diverse Prefer not to say
Income (perception)	If you take all the incomes together: How would you assess your income compared to the average German population?	Below average About the same/average (3) Above average

Table A13 Survey Items

Variable	Item	Scale
State of residency	In which federal state do you live?	Baden-Wuerttemberg Bavaria Berlin Brandenburg Bremen Hamburg Hesse Mecklenburg-Western Pomerania Lower Saxony North Rhine-Westphalia Rhineland-Palatinate Saarland Saxony Saxony-Anhalt Schleswig-Holstein Thuringia
Age	In which year were you born?	Drop-down (1921-2003)

Table A13 Survey Items

Variable	Item	Scale
Party preference	If there were a federal election next Sunday, which of the following parties would you vote for?	Die Linke (The Left) AfD (Alternative for Germany) CDU/CSU Bündnis 90/ Die Grünen (The Greens) FDP SPD Others (please name): I would not vote I am not eligible to vote Prefer not to say
Trust in senders (science/scientist and politics/politicians)	Think about the groups of people and organisations listed below. How much confidence do you have in each of these groups of people and organisations to handle the coronavirus and the pandemic situation well and correctly? Scientists Politicians	Scale from (1) Strongly disagree to (7) Strongly agree
Preferences for statistical and anecdotal evidence	(Statistical Evidence) Numbers and statistics are important to me when I evaluate information. (Anecdotal Evidence) I find personal experience more important than scientific studies.	Scale from (1) Strongly disagree to (5) Strongly agree

Table A13 Survey Items

Variable	Item	Scale
5C Vaccination attitudes	The COVID-19 vaccinations are effective. (conf 1) I have full confidence in the safety of COVID-19 vaccinations. (conf 2) As far as COVID-19 vaccinations are concerned, I trust that government authorities will always decide in the best interest of the general public. (conf 3) My immune system is so strong, it also protects me from contracting COVID-19. (comp 1) Vaccination against COVID-19 is superfluous, since diseases against which one can be vaccinated are generally rare. (comp 2) COVID-19 is not so bad that I need to be vaccinated against it. (comp 3) It is costly for me to get vaccinated against COVID-19. (const 1) My discomfort at doctor's appointments keeps me from getting vaccinated against COVID-19. (const 2) Everyday stress keeps me from getting vaccinated against COVID-19. (const 3)	Scale from (1) Strongly disagree to (7) Strongly agree

Table A13 Survey Items

Variable	Item	Scale
	I think very carefully about whether it makes sense for me to be vaccinated against COVID-19. (calc 1) A full understanding of the issue of COVID-19 vaccination is important to me before I get vaccinated. (calc 2) When I think about getting vaccinated against COVID-19, I weigh the benefits and risks to make the best possible decision. (calc 3) If everyone is vaccinated against COVID-19, I don't need to get vaccinated too. (core 1, reverse coded) I get vaccinated against COVID-19 because I can protect people with a weak immune system. (core 2) Vaccination is a community measure to prevent the spread of COVID-19. (core 3)	

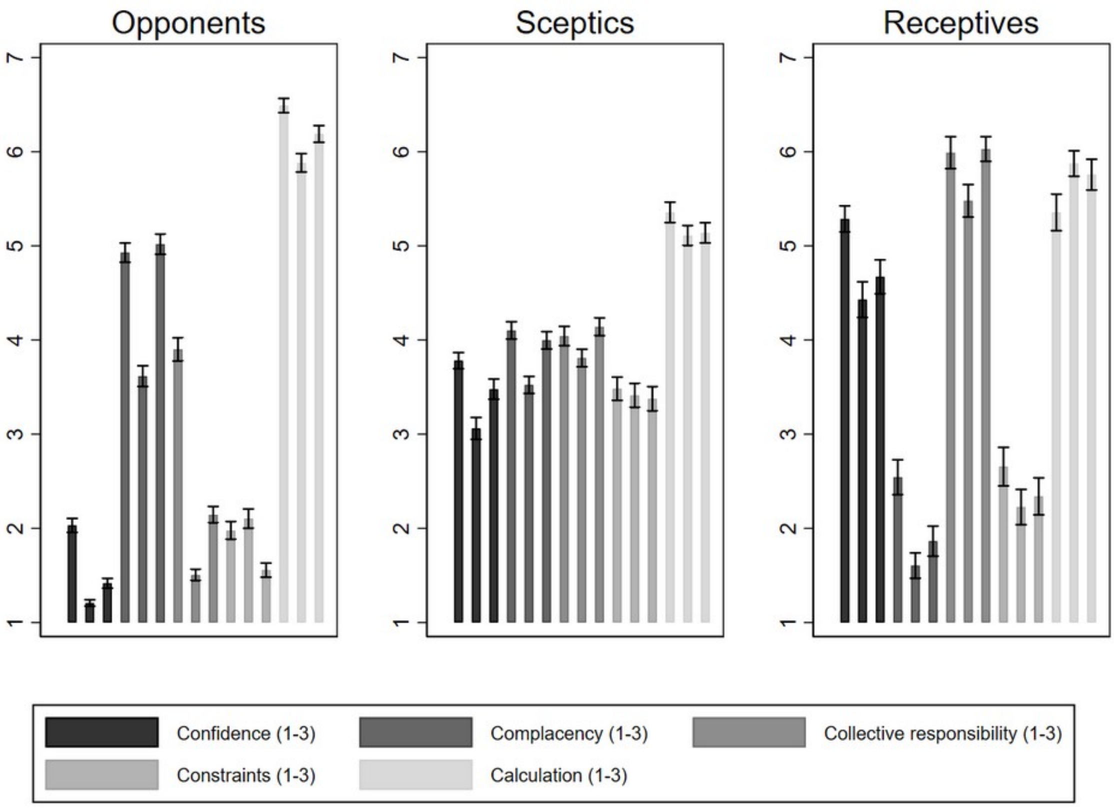

Fig. A1. Detailed Class Characteristics: 5C Scale (All 15 Items). *Notes:* Results refer to mean values of the 5C scale for vaccination attitudes, separately for each class as identified by the LCA. The mean values shown here are those of the initial 5C scale, measured on a 7-point Likert scale. See Tables A3-A5 for the condensed scale. In order to better illustrate class differences regarding the 5C vaccination hesitancy scale, the graph employs definite class assignment where respondents were assigned to the class with the maximum predicted probability.

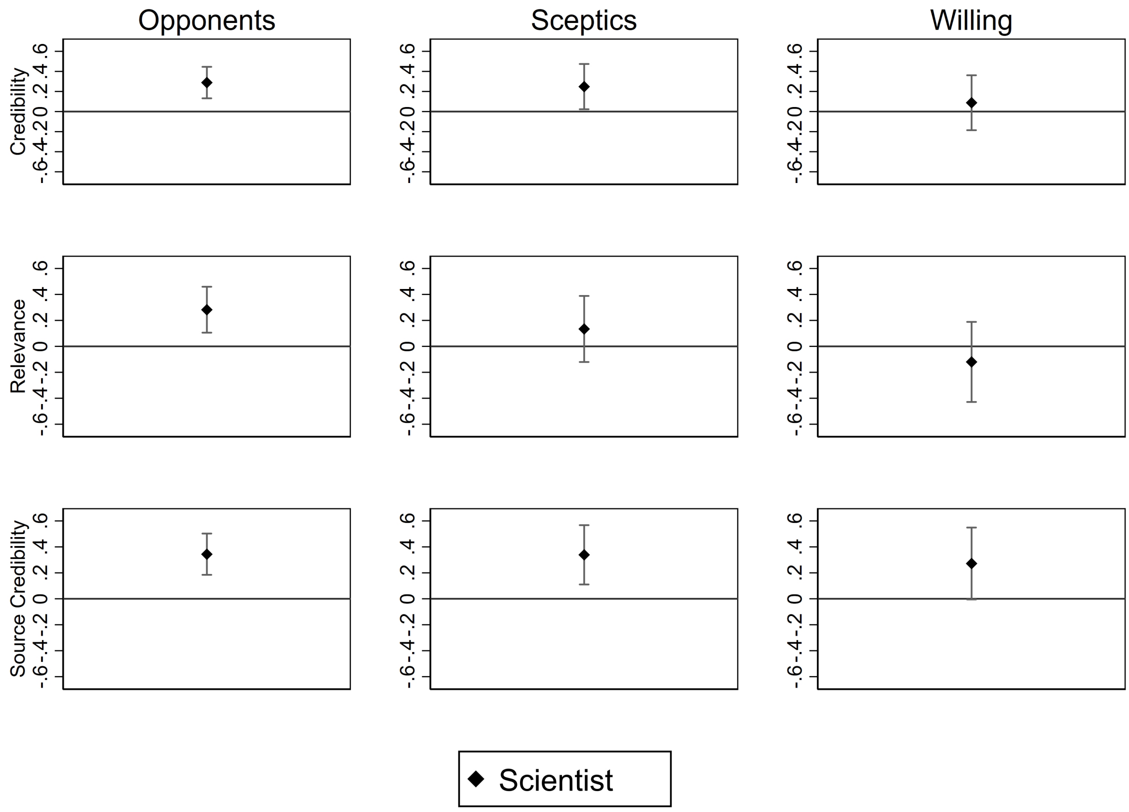

Fig. A2. Treatment Effects of Communicator on Perceived Credibility, Relevance and Source Credibility by Class of Unvaccinated. *Notes:* The figure shows boxplots of treatment effects of 1.000 simulations for each of the three classes of vaccination hesitancy. Class assignment for each respondent is based on the class membership probability which is derived from the latent class analysis. Each boxplot shows predicted values for each communicator. The reference category is a politician as communicator. The boxplot shows a 95% confidence interval. Outside values are visualized as dots (or squares). Estimations include controls for age, gender, level of education, state of residency, and level of income.

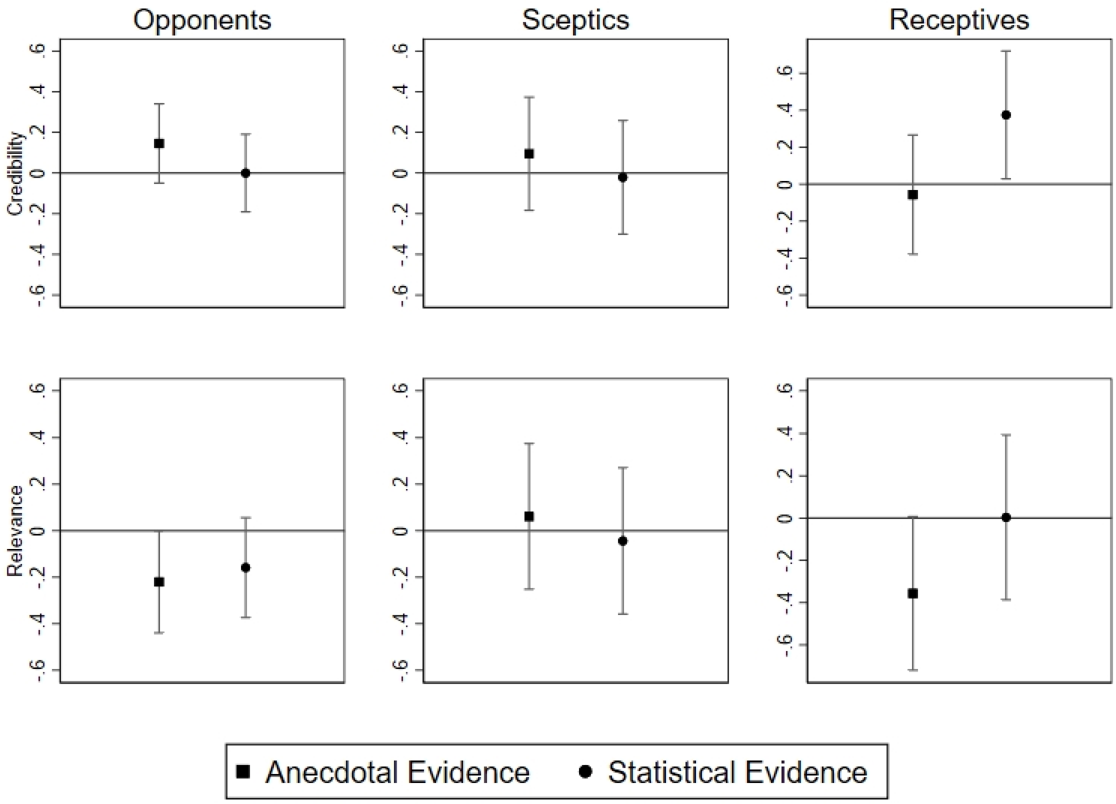

Fig. A3. Treatment Effects of Evidence on Perceived Credibility, and Relevance by Class of Unvaccinated. *Notes:* The figure shows boxplots of treatment effects of 1.000 simulations for each of the three classes of vaccination hesitancy. Class assignment for each respondent is based on the class membership probability which is derived from the latent class analysis. Each boxplot shows predicted values for each evidence type. The reference category is no evidence provision. The boxplot shows a 95% confidence interval. Outside values are visualized as dots (or squares). Estimations include controls for age, gender, level of education, state of residency, and level of income.

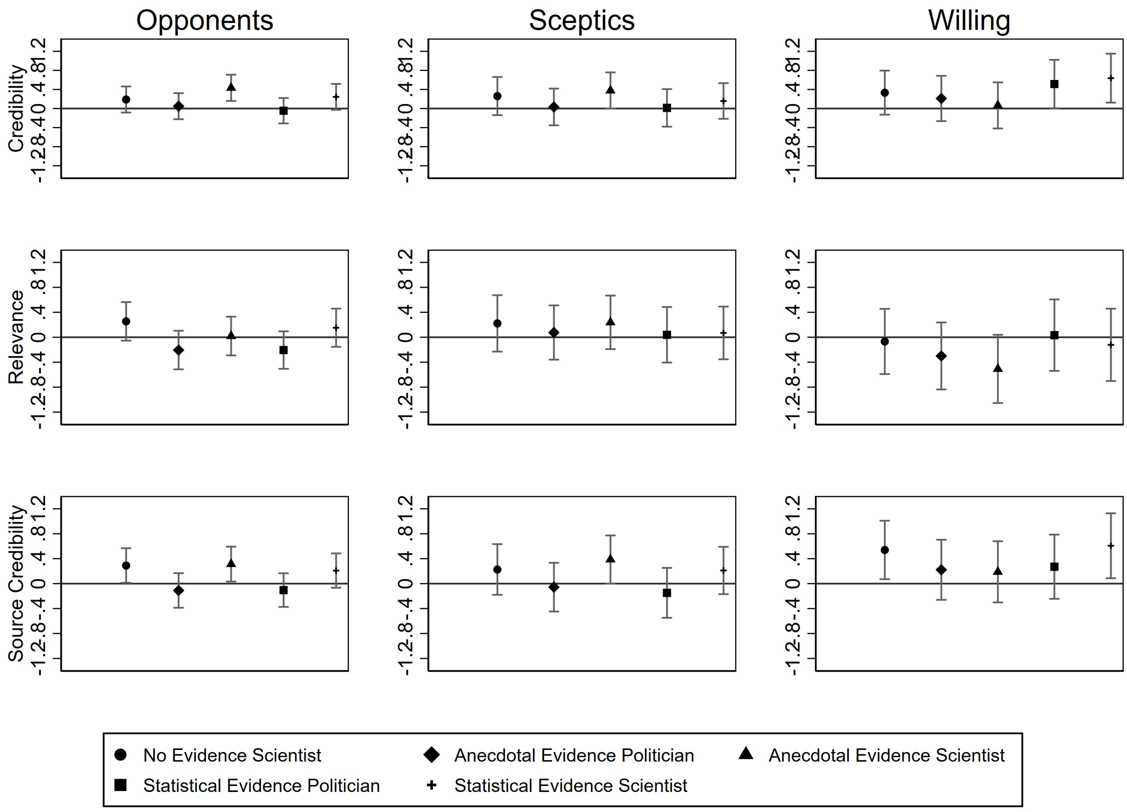

Fig. A4. Treatment Effects of Communicator and Evidence on Perceived Credibility, Relevance and Source Credibility by Class of Unvaccinated. *Notes:* The figure shows boxplots of treatment effects of 1.000 simulations for each of the three classes of vaccination hesitancy. Class assignment for each respondent is based on the class membership probability which is derived from the latent class analysis. Each boxplot shows predicted values for the combinations of evidence type and communicator. The reference category are politician communicators without any evidence provision. The boxplot shows a 95% confidence interval. Outside values are visualized as dots (or squares). Estimations include controls for age, gender, level of education, state of residency, and level of income.